Multi-Layer Network
Service or Infrastructure | Client or Server

- Multi-service
- Multi-point
- Oversubscription
- Private, Secure Bandwidth
- Low Latency
- Managed Transparency
- High Capacity Bandwidth
- Protocol Transparency
- Wholesale

Optical Network

Service Applications
Packet
Circuits
Lightpaths
Optical Network Evolution

OTN will replace SONET/SDH as foundation for optical services
Optical Transport Network (OTN) Definition

Optical Transport Network (OTN) standards defined by ITU-T G.872 and G.709
OTN Behaviors

Electrical (Digital) Domain
- OPU
- ODU
- OTU

Optical (Analog) Domain
- OCh
- OMS
- OTS

- Client Transparency
- Sub-Wavelength ODU Switching
- High Efficiency Grooming
- Pre-established Physical Links

- Client Transparency
- Full-Wavelength OCh Switching
- Wavelength Selective Bypass
- Unverified Physical Links
Three Architecture Options for OTN

**A**
- Switched G.709 (Digital OTN)
- Static WDM (Analog OTN)

- G.709 provides all dynamic capabilities
- WDM for capacity only

**B**
- Switched G.709 (Digital OTN)
- Flexible WDM (Analog OTN)

- G.709 provides dynamic switching
- WDM with reconfigurable connections

**C**
- Framed G.709 (Digital OTN)

- Dynamic WDM (Analog OTN)

- G.709 provides framing only
- WDM for all dynamic capabilities
OTN Economics & Power

Important Conclusion: Stay on the Green Line
Control Plane Applications

1. Automated Self-Inventory

2. Automated Connection Management

3. Efficient Operations

4. Self-Healing Network
1. Automated Self-Inventory

New Switch Added Here

Automatic Topology Update

Network is Database of Record

- Discover network element capabilities and availability
  - Discover neighbor connections
  - Identify peer level port associations and network layer client-server relationships
- Distribute data to NEs and NMS
  - Communicate network state updates
  - Create accurate & timely topological and resource maps
- Client inherits common server characteristics
- Define service-to-connection associations
  - Customer service and SLA tracking
2. Automated Connection Management

Point & Click Connections

- Automate turn-up and tear-down of connections
  - Signaled or Soft-permanent
  - Fast service activation
- Coordinate services across Packet, Circuit and Wavelength layers
  - Heterogeneous infrastructure
  - Lowest cost routing
  - QoS awareness
- Multi-layer complicates path computation
  - Digital connection routing
  - Analog connection routing
  - Wavelength assignment
  - Optical impairment verification
3. Efficient Operations

Traffic Redirected for Maintenance

Planned Traffic Migration

- Close cooperation between network planning & field operations
  - Design tool planning
  - Control plane execution
- Planned Line Maintenance
  - Temporary re-route of traffic around maintenance event
  - Temporarily disable links/nodes from use
- Network Defragmentation
  - Multi-layer traffic optimization
  - Periodically re-groom traffic on to cost-efficient connections as demands change
  - Increases resource utilization & minimizes cost per bit (Remember: Stay on Green Line)
4. Self-Healing Network

Disaster Recovery

- Mesh restoration across single- and multiple- administrative domains
- Sequence of multi-layer survivability
  - Optical layer first, packet layer second
  - Packet layer first, optical layer second
- Re-establishment of protection path
  - Improve connection availability by restoring BACKUP path of failed 1+1
- Multi-layer control communication
  - Layer decision: Hold off timers
  - Service priority: Contention control
  - Real-time alerts: AIS, Pre-FEC BER
  - Routing impact: Latency, SRLG
Summary

New Breed of Network Elements that participate in Multiple Network Layers

- Includes Packet, Circuit and Lightpath

Multi-Layer Switching Improves Cost & Power per Bit

- Hybrid Combination of Electrical and Analog OTN Networking

Four Applications for Control Plane Automation

- Automated Self-Inventory
- Automated Connection Management
- Efficient operations
- Self-Healing Network
Thank You

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